Check List the journal of biodiversity data

NOTES ON GEOGRAPHIC DISTRIBUTION

Check List 19 (5): 757–765
https://doi.org/10.15560/19.5.757

PENSOFT

Distribution and range extension of *Anoura cadenai* Mantilla-Meluk & Baker 2006 in the central and eastern Colombian Andes, and comments on the distribution of *A. fistulata* Muchhala, Mena-Valenzuela & Albuja 2005 in Colombia

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Abstract. *Anoura cadenai* Mantilla-Meluk & Baker, 2006 is currently known from the Pacific versant of the Cordillera Occidental of Colombia. Based on the review of additional specimens we present a range extension to the southern Cordillera Central and the western slopes of the Cordillera Oriental, extending its range by 30 km northwest, 138 km south, and 155 km southwest; our data also increase the known elevation of the species from 1600 to 1970 m a.s.l. Additionally, we present a summary of the current knowledge regarding the distribution of *A. fistulata* in Colombia.

Keywords. Andes foothills, Caquetá, Cordillera, Glossophaginae, Huila, nectarivorous bats, Phyllostomidae

Academic editor: Sergio Solari
Received 1 June 2023, accepted 20 October 2023, published 27 October 2023

Calderón-Acevedo CA, Morales-Martínez DM, Martínez-Medina D, Rodríguez-Posada ME (2023) Distribution and range extension of *Anoura cadenai* Mantilla-Meluk & Baker 2006 in the central and eastern Colombian Andes, and comments on the distribution of *A. fistulata* Muchhala, Mena-Valenzuela & Albuja 2005 in Colombia. Check List 19 (5): 757–765. https://doi.org/10.15560/19.5.757

Introduction

The genus *Anoura* Gray 1838, has 8–10 species (Calderón-Acevedo et al. 2022; Molinari et al. 2023) distributed from Central America through northern South America to Bolivia, northern Argentina, and Brazil (Griffiths and Gardner 2008), with the northern Andes hosting most of the diversity of this genus, where up to five or six can occur in sympatry (Pacheco et al. 2018; Calderón-Acevedo et al. 2022a). Colombia hosts all species of *Anoura* (Calderón-Acevedo et al. 2021; Ramírez-Chaves et al. 2022) except for *A. javieri* Pacheco et al. 2018 (Calderón-Acevedo et al. 2022a).

Anoura cadenai Mantilla-Meluk and Baker 2006 is endemic to Colombia (Mantilla-Meluk and Baker 2006; Calderón-Acevedo 2019; Calderón-Acevedo et al. 2021). This species is limited to a small region within the Chocoan slope of the Cordillera Occidental and a single location on the western slope of the Cordillera Oriental, which encompass a narrow elevation range of 800–1600

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m a.s.l. (Mantilla-Meluk and Baker 2006; Calderón-Acevedo 2019; Ramírez-Chaves et al. 2020). Despite this species' presence near or in protected areas, current threats faced by this species persist; there is ongoing decline in both the size and quality of its habitat in the western Andes (Solari 2017). Ramírez-Chaves et al. (2020) proposed a potential distribution for *A. cadenai* and restricted this species to the Cordilleras Central and Occidental (central and western Colombian Andes, respectively). They predicted a restricted distribution in dry, montane forests of the Cauca Valley and northwestern Andean forests (Ramírez-Chaves et al. 2020).

Anoura fistulata Muchhala et al. 2005 is another uncommon species of *Anoura* in Colombia. It has unique morphological adaptations to nectarivory, including the longest tongue in relation to the body size of any mammal and a glossal tube to store nectar (Muchhala 2006; Calderón-Acevedo and Muchhala 2018). This unique adaptation enables it to feed from flowers with long corollas inaccessible to other bat species (Muchhala and Thomson 2009). *Anoura fistulata* is reported from south-central Colombia to south-central Peru (Gárate-Bernardo and Carrasco-Rueda 2011; Calderón-Acevedo and Muchhala 2018; Calderón-Acevedo et al. 2022a). Most recently, new data have extended this species' range to the Colombian Massif (Morales-Martínez and Díaz 2020) and lowered the reported elevation from 1175 to 770 m a.s.l. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species have categorized both species as Data Deficient on account of unknown population trends and habitat loss. However, in comparison to *A. fistulata* (Solari 2018), *A. cadenai* exhibits significantly fragmented populations (Solari 2017), making it more susceptible to future threats.

In this study we present new records of *A. cadenai* south, southeast, and northeast of its currently known localities and present the second record from the Cordillera Oriental, adding four new localities for this species and extending its elevation range. We also provide an updated distribution of *A. fistulata* within Colombia.

Methods

We revised the specimens of *Anoura* housed at the following mammal collections: Colección de Mamíferos Alberto Cadena García, Instituto de Ciencias Naturales (ICN), Universidad Nacional, Bogotá, Colombia; American Museum of Natural History (AMNH), and the Smithsonian National Museum of Natural History (USNM). We measured the following characters to the nearest 0.01 mm: greatest length of skull, condyle-incisive length, postorbital breadth, zygomatic breadth, braincase breadth, mastoid breadth, maxillary tooth row, breadth across molars, and breadth across canines. We compared specimens of *A. cadenai* to the type series, and the taxonomic identification followed the description and recent taxonomic revisions and accounts of the genus *Anoura* (Muchhala et al. 2005; Mantilla-Meluk and Baker 2006; Griffiths and Gardner 2008; Calderón-Acevedo and Muchhala 2018, 2020; Calderón-Acevedo 2019; Calderón-Acevedo et al. 2021, 2022a). To describe the ecologic novelties in the distribution of *A. cadenai* we used the Ecoregions of the World map by Olson et al. (2001). Finally, we calculated the area of a minimum convex polygon between the points of *A. cadenai* using QGIS (QGIS.org 2016).

Results

Following our taxonomic revision of specimens previously labelled as *A. caudifer* and *A. geoffroyi*, we re-identified them as *A. cadenai*. We extend the distribution of *A. cadenai* southwest and northeast to the Cordillera Oriental (Fig. 1). These records result in an increased range of 30 km to the northwest, 150 km to the southeast, and 138 km to the south of the previously known localities (Table 1) and increase its known upper elevation limit from 1600 to 1970 m a.s.l. Our morphological identification concurs with the recent molecular phylogenetic assessment of the genus, which included some of these specimens (Calderón-Acevedo et al. 2022a, 2022b). Additionally, we report on ecological extensions to the eastern versant of the Cordillera Central and the western versant of the Cordillera Oriental in Colombia, including the five ecoregions shown in Figure 2.

Anoura cadenai Mantilla-Meluk & Baker, 2006

New records. COLOMBIA – **Department of Cundinamarca** • Municipality of San Juan de Río Seco; 04.85, −074.63; Nicéforo Maria leg.; 1 sex indet., USNM 252016 – **Department of Huila** • Municipality of Teruel, vereda Corrales, farm El Diamante, Las Nubes stream; 02.84, −075.61; 1970 m a.s.l.; 16.II.2010; Miguel E. Rodríguez-Posada leg.; 1 ♂, ICN 21197 • Municipality of Paicol, vereda Santa Inés, Caja de Agua cave; 02.42, −075.77; 1000 m a.s.l.; 27.II.2005; Luis G. Sánchez leg.; 1 ♀, ICN 17747 – **Department of Cauca** • Municipality of Piendamó; 02.68, −076.57; 25.I.1972; R.E Goodwin leg.; 1 sex indet., AMNH 269477 – **Department of Valle del Cauca** • Municipality of Yotoco; Yotoco Natural Forest Reserve; 03.87, −076.43; 1634 m a.s.l.; 2.IX.2009; Eyda Moreno Mosquera leg.; 1 ♂, ICN 22806.

Identification. *Anoura cadenai* can be differentiated from the large-bodied *Anoura* species (*A. cultrata*, *A. geoffroyi*, and *A. latidens*) by the following characters (Handley 1960, 1984; Mantilla-Meluk and Baker 2006; Calderón-Acevedo 2019): 1) lack of a blade-like lower first premolar compared to *A. cultrata* (Fig. 3); 2) lack of the median internal cusp of the last upper premolar (Fig. 3); and 3) a first lower molar lacking the antero-external cuspid and cristid, which is present in *A. geoffroyi* and *A. latidens* (Fig. 3). *Anoura cadenai* is distinguishable from the small-bodied *Anoura* species by its unique cranial characteristics (such as the posteriorly flattened keel along the midline of the mesopterygoid

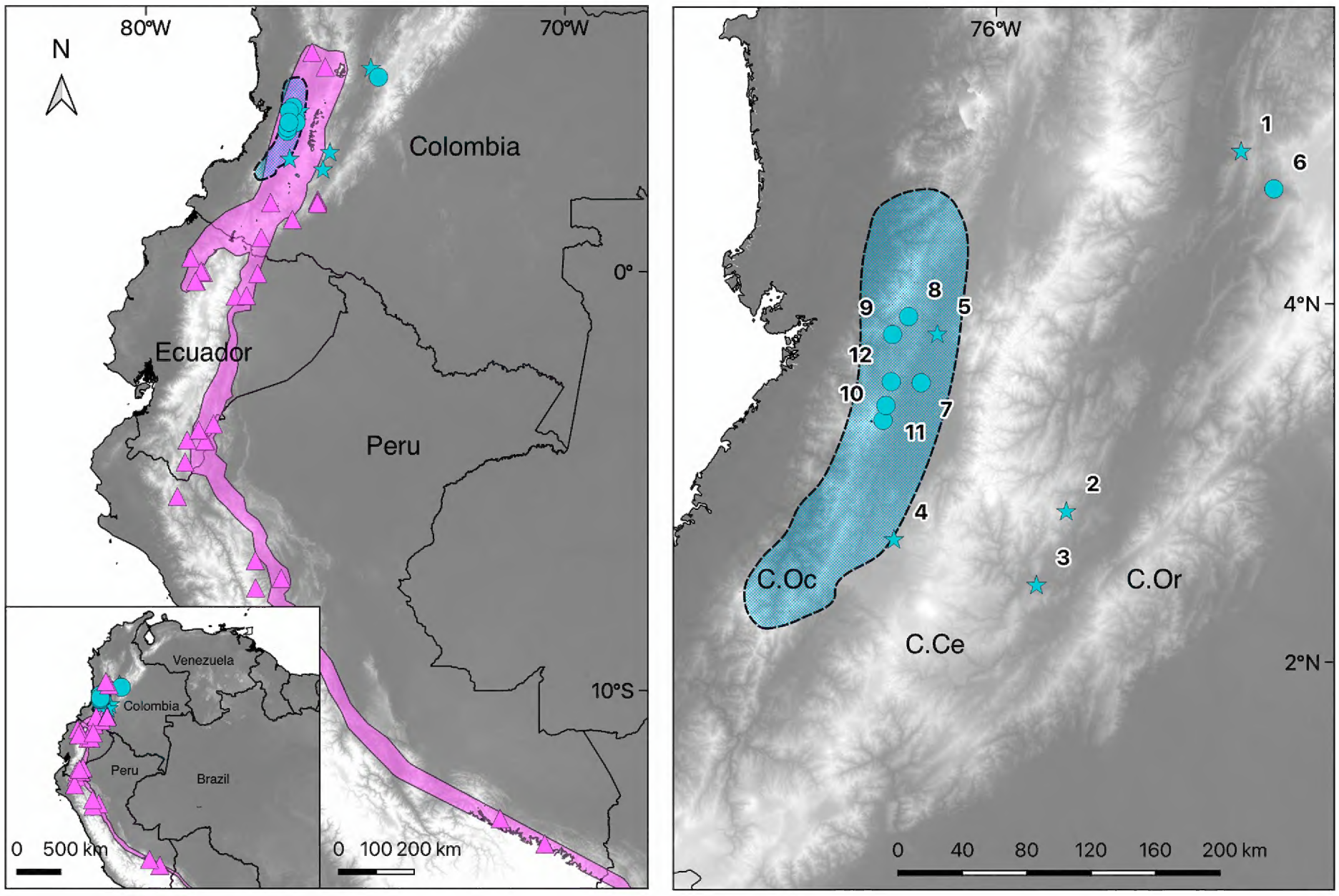

Figure 1. Known distribution of *Anoura cadenai* (circles, delimited by dotted line, in blue) and *A. fistulata* (triangles, delimited by solid line, in pink) from Solari (2017, 2018) and Rojas et al. (2018). Stars denote new localities, numbers correspond to "Locality" in Table 2. Localities 1–5 represent new localities of *A. cadenai* in the Cordillera Central (C.Ce) and Oriental (C.Or). C.Co = Cordillera Oriental, C.Ce = Cordillera Central, C.Oc = Cordillera Occidental. Colour scale denotes elevation from low (grey) to white (high).

Table 1. Measurements of new records of *Anoura cadenai* compared to previous taxonomical revision (Mantilla-Meluk and Baker 2006; Calderón-Acevedo and Muchhala 2018). Measurements in mm. GLS = greatest length of skull; CIL = condyle-incisive length; PB = postorbital breadth; ZB = zygomatic breadth; BB = braincase breadth; MB = mastoid breadth; C-M3 = maxillary tooth-row length; M3-M3 = breadth across third upper molars; C-C = breadth across upper canines.

	ICN 17747	ICN 21197	ICN 22806	AMNH 269477	USNM 252016	Mean
GLS	22.93	22.28	22.99	23.52	24.18	23.06 (SD = 0.66, *N* = 17)
CIL	22.36	22.02	22.73	23.18	23.48	22.55 (SD = 0.64, *N* = 17)
PB	4.61	4.41	4.73	4.72	2.91	4.59 (SD = 0.11, *N* = 17)
ZB	?	9.56	?	9.47	?	9.89 (SD = 0.36, *N* = 16)
BB	8.67	8.67	8.98	9.09	?	9.06 (SD = 0.12, *N* = 16)
MB	9.30	9.79	9.17	9.6	?	9.53 (SD = 0.28, *N* = 16)
C-M3	8.50	8.27	8.45	8.95	9.05	8.60 (SD = 0.28, *N* = 17)
M3-M3	5.73	5.62	6.05	5.91	5.84	5.89 (SD = 0.19, *N* = 16)
C-C	3.98	4.42	4.19	4.30	4.45	4.24 (SD = 0.17, *N* = 17)

fossa, posterior projection of the pterygoids short, extending to the anterior projection of each bulla, and with robust upper canines resembling those of *A. cultrata* (Fig. 3)) and the sparsely haired uropatagium (Mantilla-Meluk and Baker 2006; Griffiths and Gardner 2008; Calderón-Acevedo et al. 2021; Fig. 4). All five specimens of *A. cadenai* presented here show the diagnostic characters differentiating them from large-bodied *Anoura*, while concurring with the characters of its diagnosis. The craniodental measurements also fall within the expected ranges for this species and do not overlap with closely related smaller species (*A. caudifer* and *A. luismanueli*) (Table 2), although measurements of *A. fistulata* and *A. cadenai* can overlap (Calderón-Acevedo and Muchhala 2018; Calderón-Acevedo 2019). The lack of a developed slender, fine-pointed lower lip protruding 4 mm (Fig. 4) and a more robust skull with a less-developed mandibular symphysis clearly separates *A. cadenai* from *A. fistulata* (Calderón-Acevedo and Muchhala 2018; Calderón-Acevedo 2019).

Table 2. Localities of known records of *Anoura cadenai* and *A. fistulata*. Locality number denotes a locality in the map (Figs. 1, 2). Catalogue numbers or publication citation is given for the records. * = specimens from the type series, † = holotype specimen and locality.

Species	Locality	Catalog no.	Country	Department	Municipality	Longitude	Latitude
A. cadenai	1	USNM 252016	Colombia	Cundinamarca	San Juan de Río seco	–74.633	004.850
A. cadenai	2	ICN 21197	Colombia	Huila	Teruel	–75.610	002.840
A. cadenai	3	ICN 17747	Colombia	Huila	Paicol	–75.776	002.428
A. cadenai	4	AMNH 269477	Colombia	Cauca	Piendamó	–76.572	002.683
A. cadenai	5	ICN 22806	Colombia	Valle del Cauca	Yotoco	–76.438	003.877
A. cadenai	6	ANDES-M-2591	Colombia	Cundinamarca	La Mesa	–74.450	004.643
A. cadenai	7	ICN 8892	Colombia	Valle del Cauca	Calima	–76.420	003.560
A. cadenai	8	ICN 9152†	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	8	ICN 8893*	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	8	ICN 8894*	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	8	ICN 9151*	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	8	ICN 9152*	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	8	ICN 9153*	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	8	ICN 9154*	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	8	ICN 9155	Colombia	Valle del Cauca	Calima	–76.490	003.930
A. cadenai	9	ICN 9156	Colombia	Valle del Cauca	Calima	–76.580	003.830
A. cadenai	10	USNM 483366*	Colombia	Valle del Cauca	Cali	–76.633	003.350
A. cadenai	10	USNM 483367*	Colombia	Valle del Cauca	Cali	–76.633	003.350
A. cadenai	10	USNM 483368*	Colombia	Valle del Cauca	Cali	–76.633	003.350
A. cadenai	10	USNM 483369*	Colombia	Valle del Cauca	Cali	–76.633	003.350
A. cadenai	10	USNM 483370*	Colombia	Valle del Cauca	Cali	–76.633	003.350
A. cadenai	11	USNM 483371*	Colombia	Valle del Cauca	Cali	–76.617	003.433
A. cadenai	12	UV 14761	Colombia	Valle del Cauca	La Cumbre	–76.587	003.566
A. fistulata	13	MHNUCA:Mammal:678	Colombia	Risaralda	Marsella	–75.720	004.886
A. fistulata	13	MHNUCA:Mammal:679	Colombia	Risaralda	Marsella	–75.720	004.886
A. fistulata	14	FMNH 113512	Colombia	Nariño	Llorente	–77.250	000.817
A. fistulata	15	ICN 11461	Colombia	Risaralda	Pueblo Rico	–76.036	005.238
A. fistulata	16	ICN 19130	Colombia	Cauca	Santa Rosa, Serrania de los Churumbelos	–76.508	001.242
A. fistulata	17	ICN 19653	Colombia	Nariño	Genova	–77.024	001.646
A. fistulata	18	ICN 23718	Colombia	Caquetá	Belén de los Andaquíes	–75.903	001.718
A. fistulata	19	ICN 23719	Colombia	Caquetá	Belén de los Andaquíes	–75.903	001.671
A. fistulata	20	ICN 23720	Colombia	Caquetá	Belén de los Andaquíes	–75.906	001.631
A. fistulata	20	ICN 23721	Colombia	Caquetá	Belén de los Andaquíes	–75.906	001.631
A. fistulata	21	Muchhala et al. 2005	Ecuador	Pichincha	Bellavista	–78.684	–000.002
A. fistulata	22	Muchhala et al. 2005	Ecuador	Pichincha	Guajalito	–78.800	–000.219
A. fistulata	23	Muchhala et al. 2005	Ecuador	Pichincha	Pahuma	–78.633	–000.018
A. fistulata	24	Muchhala et al. 2005	Ecuador	Pichincha	Yanayacu	–77.869	–000.584
A. fistulata	25	Muchhala et al. 2005	Ecuador	Zamora Chinchipe	La Herradura	–78.570	–004.034
A. fistulata	26	Muchhala et al. 2005	Ecuador	Zamora Chinchipe	Chinapiuza	–78.594	–04.039
A. fistulata	27	Muchhala et al. 2005	Ecuador	Zamora Chinchipe	Cuevas de Numbala	–79.068	–004.547
A. fistulata	28	Muchhala et al. 2005	Ecuador	Zamora Chinchipe	Destacamento Militar Condor	–78.389	–003.636
A. fistulata	29	Lee et al. 2010	Ecuador	Imbabura	Santa Rosa	–78.932	000.331
A. fistulata	30	ACUNHC_1352	Ecuador	Napo	Sumaco	–77.601	–000.572
A. fistulata	31	Rex et al. 2008	Ecuador		Parque Nacional Podocarpus	–79.017	–004.017
A. fistulata	32	Gárate-Bernardo & Carrasco-Rueda 2011	Peru	Puno	Ollacea	–70.482	–013.662
A. fistulata	33	Jimenez et al. 2008 / Pacheco et al. 2009	Peru	San Martin	Huicungo	–76.773	–007.320

Species	Locality	Catalog no.	Country	Department	Municipality	Longitude	Latitude
A. fistulata	34	MUSM 37883 (Pacheco et al. 2018)	Peru	Cajamarca	San Ignacio	–79.251	–005.365
A. fistulata	35	MUSM 8750 (Pacheco et al. 2018)	Peru	Cuzco	San Perdro	–71.546	–013.055
A. fistulata	36	MUSM 7215, 7221 (Pacheco et al. 2018)	Peru	San Martin	Las Palmas	–77.383	–007.550
A. fistulata	37	MUSM 24363 (Pacheco et al. 2009, 2018)	Peru	San Martin	La Meseta	–71.391	–006.895
A. fistulata	38	ACUNHC 894	Ecuador	Pichincha	Tandayapa	–78.683	000.005
A. fistulata	39	Jarrin-V and Coello 2012	Ecuador	Pichincha		–78.820	–000.230
A. fistulata	40	Jarrin-V and Coello 2012	Ecuador	Sucumbios	Los Cedros	–77.333	–000.043
A. fistulata	41	Jarrin-V and Coello 2012	Ecuador	Zamora Chinchipe	Chinapiuza	–78.746	–003.777

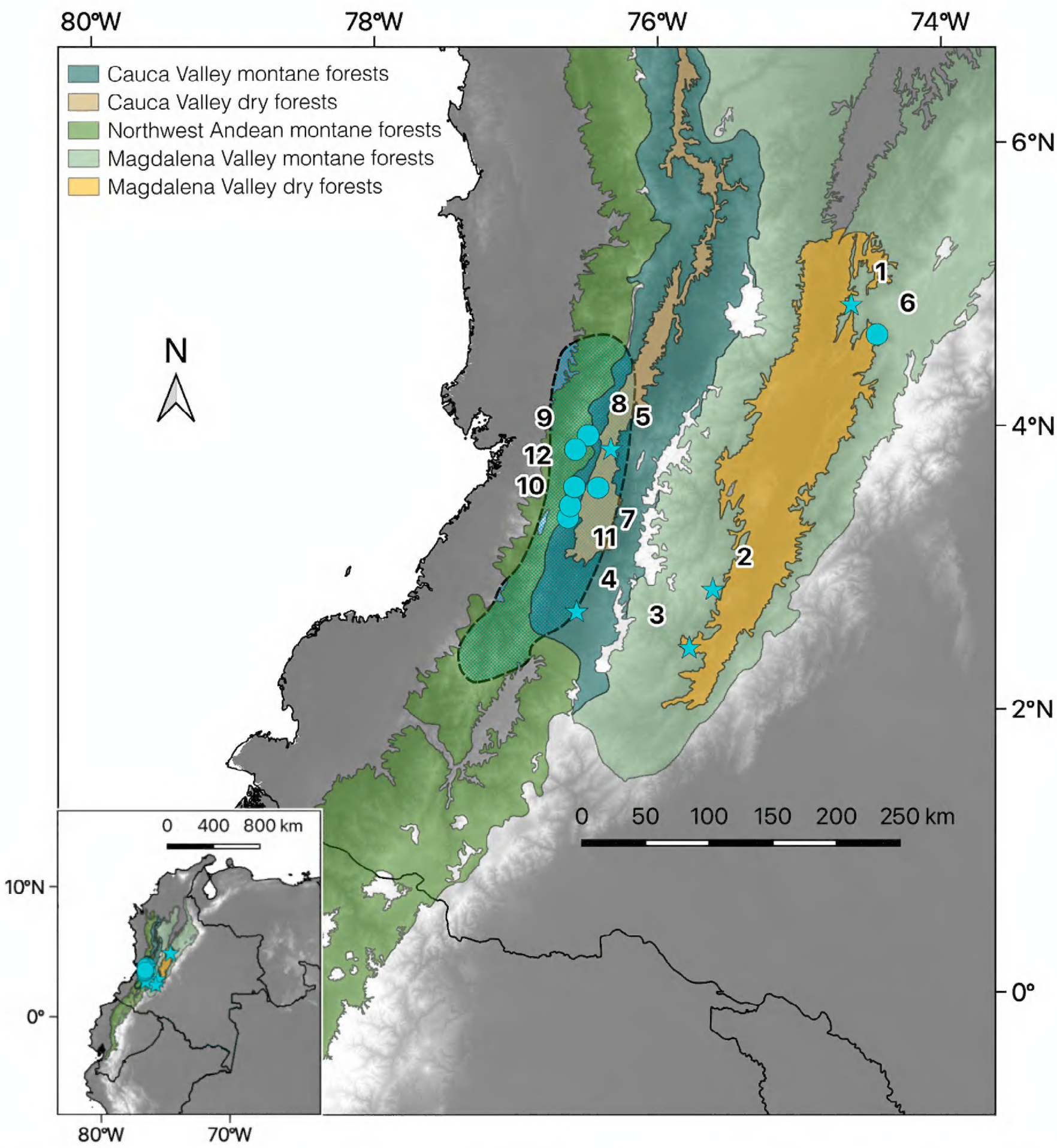

Figure 2. Ecoregion types where *Anoura cadenai* is reported. Most of the current records come from the Montane and Dry Cauca Valley Forests, and the Northwest Andean Forests, while the new records add the montane and dry forests of the Magdalena river valley. Stars denote newly added localities.

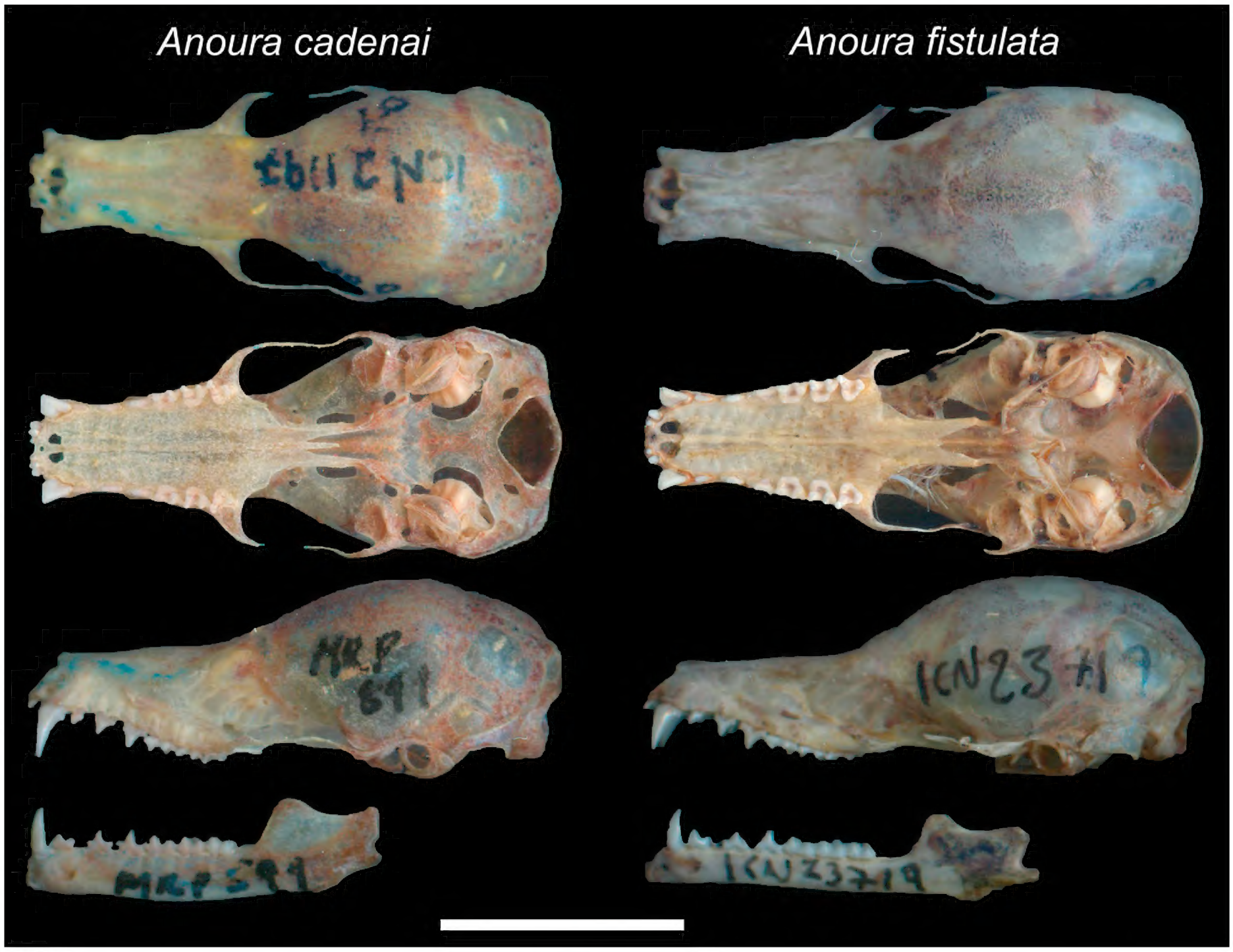

Figure 3. Dorsal, ventral, and lateral view of the skull and lateral view of mandible of (**left**) *Anoura cadenai* (ICN 21197) from Teruel, Huila Department and (**right**) *Anoura fistulata* (ICN 23719) from Belén de los Andaquíes, Caquetá Department. Scale bar = 10 mm.

Discussion

The northern tropical Andes stand out as one of the most diverse hotspots globally. In recent years, the Cordillera Oriental in the eastern Colombian Andes has gained recognition as a significant hub for the discovery of new species (Ramírez-Chaves et al. 2020; Rodríguez-Posada et al. 2021) and for documenting previously poorly known ones (Ramírez-Chaves and Suárez-Castro 2014; de Roux et al. 2019; Morales-Martínez and Díaz 2020; García-Restrepo et al. 2023). Among these findings are the two *Anoura* species presented in this study, underscoring the area's immense potential as habitat for undocumented and undescribed mammal species.

Species of *Anoura* are characterized by their adaptability and extensive distributional ranges, with some species capable of thriving across altitudes from 0 to 3000 m a.s.l. (Molinari 1994; Soriano et al. 2002; Pacheco et al. 2018; Calderón-Acevedo and Muchhala 2020). The new localities of *A cadenai* presented here expand the distribution of this species to the Magdalena Valley montane and dry forests. These two ecoregions extend north of its current distribution and could represent potentially suitable habitat for this species. Furthermore, these data suggest that *A. cadenai* may be more common than previously thought, and its distribution could extend north of the eastern Andes. Interestingly, the species only occurs in the dry versant of the three cordilleras of Colombia, contrary to *A. fistulata*, which resides in very humid habitats (Muchhala et al. 2005; Mantilla-Meluk and Baker 2008; Gárate-Bernardo and Carrasco-Rueda 2011; Mantilla-Meluk et al. 2014; Calderón-Acevedo and Muchhala 2018). This suggests that despite the wide geographical distribution ranges of *Anoura* species, their local distributions could be limited by specific habitat requirements and the local environment. However, the influence of biotic and abiotic environmental conditions on the diversification of the genus is still unknown.

Recent delimitation and descriptions of *Anoura* species have come from museum specimens previously identified as *A. caudifer* or *A. geoffroyi* (Molinari 1994; Muchhala et al. 2005; Mantilla-Meluk and Baker 2006; Pacheco et al. 2018). In some cases, misidentification has led to describing new species, or reporting or delisting species (Calderón-Acevedo and Muchhala 2018; 2020; Calderón-Acevedo et al. 2021). Therefore, it is important to consider that the current understanding of the distribution of both *A. cadenai* and *A. fistulata* in Colombia could be product of inadequate sampling of the Andean cordilleras in the country. Such a scenario creates a scarcity of materials for contrasting intra- and

Figure 4. Photographs of *Anoura cadenai* (**A, C**) and *A. fistulata* (**B, D**). Although there is a slight similarity of the lower lip in both species, *A. cadenai* has a robust rostrum and a round lower lip while *A. fistulata* has narrower rostrum and arrowhead-shaped lower lip protruding 4 mm or more. The uropatagium of both species is V-shaped.

interspecific variation; this rarity is reinforced by the lack of external morphological characters that allow for a clear field identification and diagnosis.

Data deficiency and anthropogenic disturbances are two threats that loom over most bat species, especially in the Neotropics (Frick et al. 2020; Soto-Centeno and Calderón-Acevedo 2023). New locality records, especially for poorly known species, have the potential to change our current understanding of a species' conservation status and support its recategorization. By extending the geographic range of *A. cadenai* 30 km northeast, 150 km southeast, 138 km south, and combining our new records with previously known localities (Mantilla-Meluk and Baker 2006, Calderón-Acevedo 2019), we calculated a minimum polygon encompassing an area of 36,172 km^2, which is an increase of 222% from the assessed Extent of Occurrence of 16,249 km^2.

Anoura fistulata is known only from 31 localities in northern South America, which significantly affects its conservation status and local bat-conservation programs (Calderón-Acevedo and Muchhala 2018). Hence, the inclusion of confirmed localities becomes vital for future conservation assessments in Colombia, particularly as the national Red List of mammals is currently being reassessed. The distribution of *A. fistulate*, as is currently known, encompasses a wide altitude range from 770 to 2517 m a.s.l. in the eastern versant of the Andean cordillera south to Ecuador, and in the Chocó (western) and Amazon (eastern) versants of the Andes in Ecuador and Colombia.

It has been assumed that *A. fistulata* exhibits a condition of rarity, presumably related to a co-evolutionary relationship with some species of Campanulaceae (Mantilla-Meluk et al. 2014; Muchhala and Thomson 2009). However, preliminary observations of the captures in Andakí Natural Park show that *A. fistulata* is locally common at 770–1900 m a.s.l., which might be a pattern seen in other localities where netting effort has been less; this must be considered in future studies (Morales-Martínez and Díaz 2020).

Acknowledgements

We thank C. Cardenas and H. López-Arevalo from the Alberto Cadena Garcia mammal collection at Instituto de Ciencias Naturales of Universidad Nacional de Colombia, N.B. Simmons, N. Duncan and the staff of the mammal collection of the American Museum of Natural History, as well as D. Lunde of the Smithsonian National Museum of Natural History for their assistance while revising these collections. CAC's work during the writing of this manuscript was partly funded by a post-doctoral scholarship at the Soto Lab of Bat Biology (SLaBB) at Rutgers University Newark. DMMM thanks Ministerio de Ciencia Tecnología e Innovación and the Fulbright-Colombia commission for support-

ing his doctoral studies through the Fulbright-MinCiencias 2022 scholarship. We thank the editor and two reviewers who provided constructive feedback that improved this manuscript.

Author Contributions

Conceptualization: CAC, MERP, DMMM. Data curation: DMM, DMMM, MERP, CAC. Formal analysis: CAC, DMMM. Funding acquisition: CAC. Methodology: CAC, DMMM. Writing – original draft: CAC, DMMM, DMM, MERP. Writing – review and editing: MERP, CAC, DMMM, DMM. Visualization: CAC, DMMM

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